US009305954B2

(12) **United States Patent**
Kato et al.

(10) **Patent No.: US 9,305,954 B2**
(45) **Date of Patent: Apr. 5, 2016**

(54) **SOLID-STATE IMAGE SENSOR AND CAMERA UTILIZING LIGHT ATTENUATING FILMS**

(71) Applicant: **CANON KABUSHIKI KAISHA**, Tokyo (JP)

(72) Inventors: **Satoshi Kato**, Kawasaki (JP); **Hideo Kobayashi**, Tokyo (JP); **Masanori Ogura**, Tokyo (JP); **Yukihiro Kuroda**, Inagi (JP)

(73) Assignee: **Canon Kabushiki Kaisha**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/200,730**

(22) Filed: **Mar. 7, 2014**

(65) **Prior Publication Data**

US 2014/0253767 A1 Sep. 11, 2014

(30) **Foreign Application Priority Data**

Mar. 11, 2013 (JP) 2013-048489

(51) **Int. Cl.**
H01L 27/146 (2006.01)
H04N 5/355 (2011.01)
H04N 9/04 (2006.01)

(52) **U.S. Cl.**
CPC ***H01L 27/14625*** (2013.01); ***H01L 27/14621*** (2013.01); ***H04N 5/35563*** (2013.01); ***H04N 9/045*** (2013.01)

(58) **Field of Classification Search**
CPC H04N 5/35563
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,121,225 A 6/1992 Murata et al.
5,261,013 A 11/1993 Murata et al.
5,475,211 A 12/1995 Ogura et al.
6,787,824 B2 9/2004 Takeuchi et al.
6,831,692 B1 * 12/2004 Oda H01L 27/14621 250/208.1
7,227,208 B2 6/2007 Ogura et al.
7,321,110 B2 1/2008 Okita et al.
7,408,210 B2 8/2008 Ogura et al.
7,456,880 B2 11/2008 Okita et al.
7,460,162 B2 12/2008 Koizumi et al.
7,514,732 B2 4/2009 Okita et al.
7,550,793 B2 6/2009 Itano et al.
7,605,415 B2 10/2009 Koizumi et al.
7,629,568 B2 12/2009 Koizumi et al.
7,638,826 B2 12/2009 Hiyama et al.
7,679,658 B2 3/2010 Sakurai et al.
7,719,587 B2 5/2010 Ogura et al.
7,741,593 B2 6/2010 Iwata et al.

(Continued)

FOREIGN PATENT DOCUMENTS

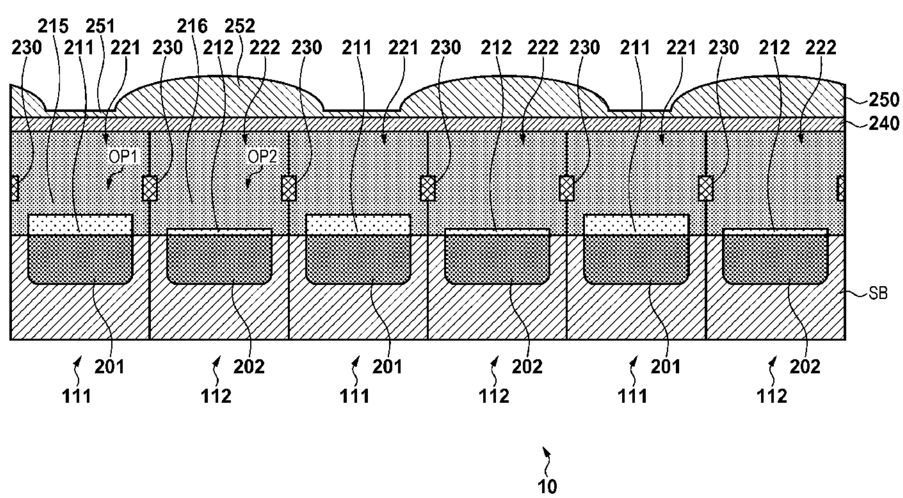
JP 2004032059 A 1/2004

Primary Examiner — Albert Cutler
(74) *Attorney, Agent, or Firm* — Fitzpatrick, Cella, Harper & Scinto

(57) **ABSTRACT**

A sensor has first pixels each including one of red, green and blue color filters, and second pixels each including one of red, green and blue color filters. In the first and second pixels including color filters of the same color, light transmittances of the light transmissive portions are different. A light transmittance of the light transmissive portion of the first pixel including the red color filter is lower than that of the light transmissive portion of the first pixel including the green color filter, and a light transmittance of the transmissive portion of the first pixel including the green color filter is lower than that of the light transmissive portion of the first pixel including the blue color filter.

12 Claims, 14 Drawing Sheets



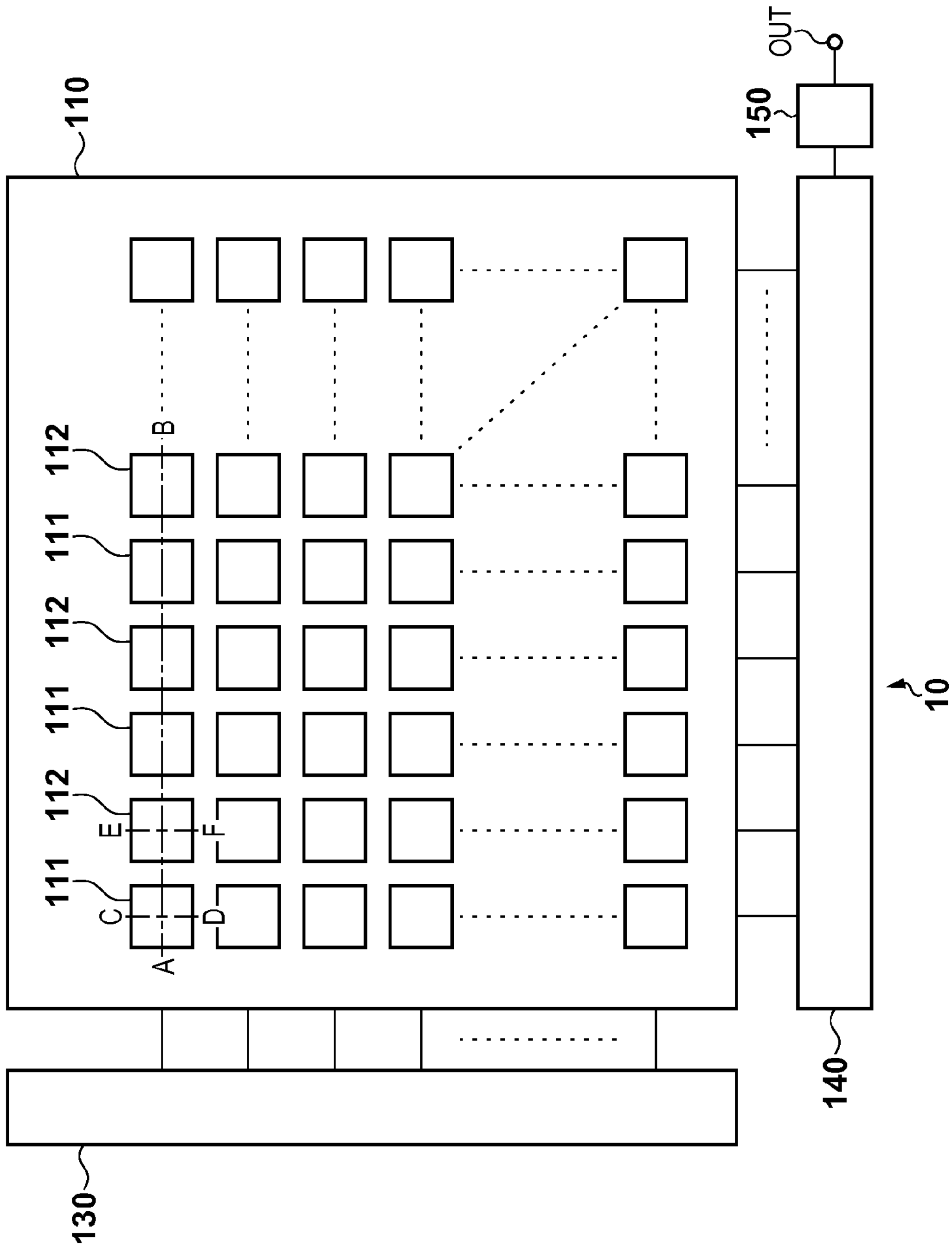
(56) **References Cited**

U.S. PATENT DOCUMENTS

7,808,537	B2	10/2010	Fujimura et al.	
7,812,873	B2	10/2010	Hiyama et al.	
7,812,876	B2	10/2010	Hiyama et al.	
7,817,199	B2	10/2010	Yamashita et al.	
7,906,755	B2	3/2011	Koizumi et al.	
7,907,196	B2	3/2011	Ogura et al.	
7,911,521	B2	3/2011	Kuroda et al.	
7,935,995	B2	5/2011	Watanabe et al.	
7,943,975	B2	5/2011	Koizumi et al.	
7,948,540	B2	5/2011	Ogura et al.	
7,978,241	B2	7/2011	Koizumi et al.	
7,990,440	B2	8/2011	Kobayashi et al.	
8,053,718	B2	11/2011	Koizumi et al.	
8,063,958	B2	11/2011	Okita et al.	
8,084,729	B2	12/2011	Kato et al.	
8,134,190	B2	3/2012	Okita et al.	
8,154,639	B2	4/2012	Kato et al.	
8,159,582	B2	4/2012	Kato et al.	
8,169,525	B2	5/2012	Ryoki et al.	
8,174,599	B2	5/2012	Kuroda et al.	
8,174,600	B2	5/2012	Ogura et al.	
8,207,561	B2	6/2012	Koizumi et al.	
8,218,050	B2	7/2012	Ogura et al.	
8,222,682	B2	7/2012	Watanabe et al.	
8,223,238	B2	7/2012	Kuroda et al.	
8,309,898	B2	11/2012	Kato et al.	
8,345,137	B2	1/2013	Shinohara et al.	
8,390,708	B2	3/2013	Koizumi et al.	
8,390,713	B2	3/2013	Kuroda et al.	
8,411,178	B2	4/2013	Ogura et al.	
8,416,329	B2	4/2013	Hiyama et al.	
8,441,558	B2	5/2013	Okita et al.	
8,477,224	B2	7/2013	Ogura et al.	
8,493,487	B2	7/2013	Takada et al.	
8,520,102	B2	8/2013	Ogura et al.	
8,520,108	B2	8/2013	Ogura et al.	
8,552,481	B2	10/2013	Hiyama et al.	
8,624,307	B2	1/2014	Koizumi et al.	
8,670,058	B2	3/2014	Hayashi et al.	
8,675,107	B2	3/2014	Yamashita et al.	
8,698,935	B2	4/2014	Okita et al.	
8,710,558	B2	4/2014	Inoue et al.	
8,749,675	B2	6/2014	Koizumi et al.	
2004/0017497	A1*	1/2004	Suzuki et al.	348/315
2004/0109068	A1*	6/2004	Mitsunaga et al.	348/222.1
2007/0296843	A1	12/2007	Kasuga et al.	
2008/0265349	A1*	10/2008	Kasano	G03B 11/00 257/432
2009/0284630	A1*	11/2009	Itonaga	348/294
2009/0298220	A1*	12/2009	Anderson et al.	438/70
2010/0013969	A1	1/2010	Ui	
2010/0314530	A1	12/2010	Hiyama et al.	
2011/0141333	A1*	6/2011	Naruse	H01L 27/14621 348/308
2011/0228149	A1*	9/2011	Naruse	H01L 27/14627 348/273
2011/0278438	A1	11/2011	Kobayashi	
2012/0273657	A1	11/2012	Kobayashi	
2013/0063635	A1	3/2013	Kobayashi	
2013/0082343	A1	4/2013	Fudaba et al.	
2013/0140440	A1	6/2013	Kobayashi	
2013/0140608	A1	6/2013	Kuroda et al.	
2013/0140665	A1	6/2013	Koizumi et al.	
2013/0194470	A1	8/2013	Ogura et al.	
2013/0221199	A1	8/2013	Kato	
2013/0313413	A1	11/2013	Kato	
2013/0313622	A1	11/2013	Kuroda	
2014/0002690	A1	1/2014	Hiyama et al.	
2014/0320695	A1*	10/2014	Ozawa	H04N 5/35563 348/229.1

* cited by examiner

FIG. 1



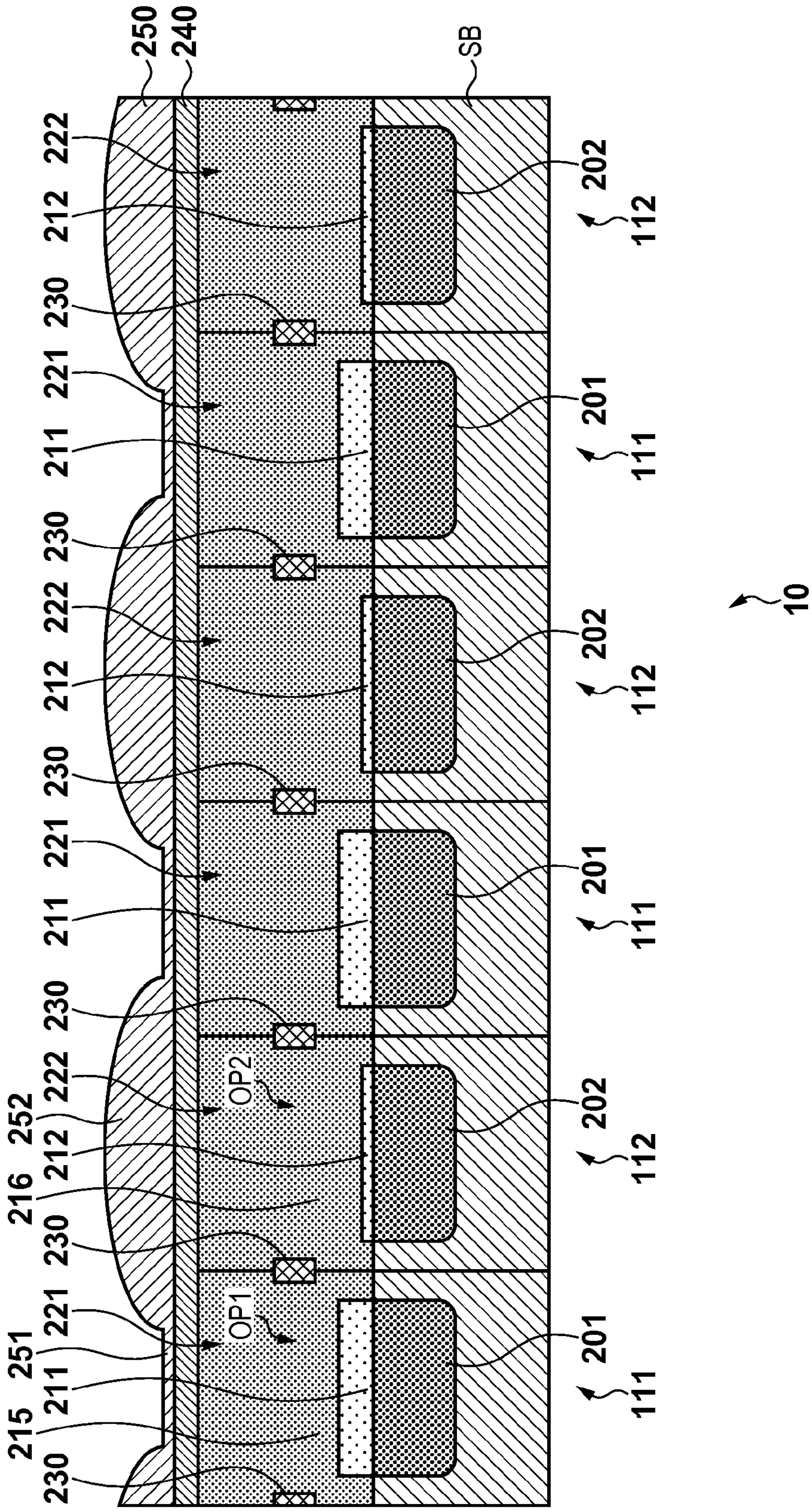
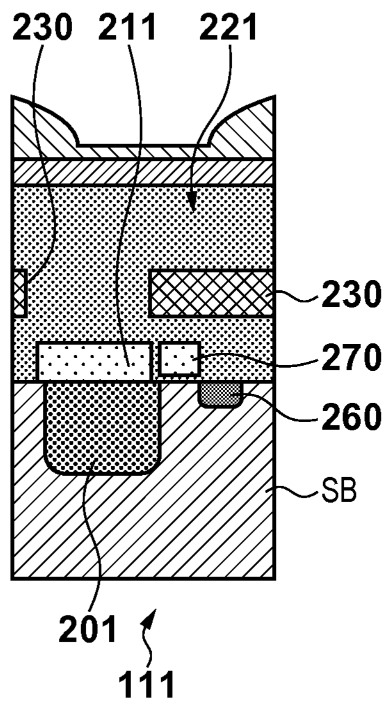

250
240
SB
222
212
230
221
211
202
112
201
111
10
252
216
OP2
OP1
251
215

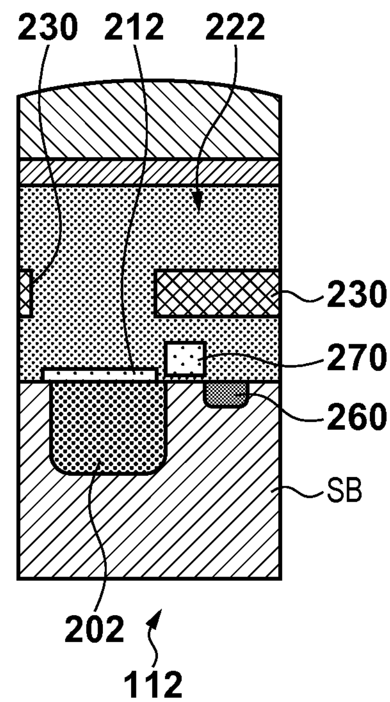
FIG. 2

FIG. 3A



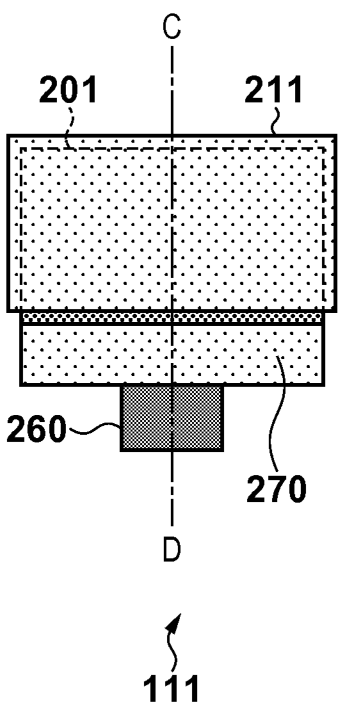
C-D SECTION

FIG. 3B

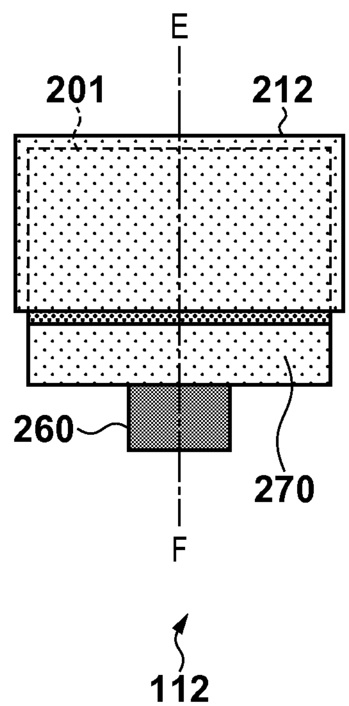


E-F SECTION

F I G. 4A



F I G. 4B



F I G. 5

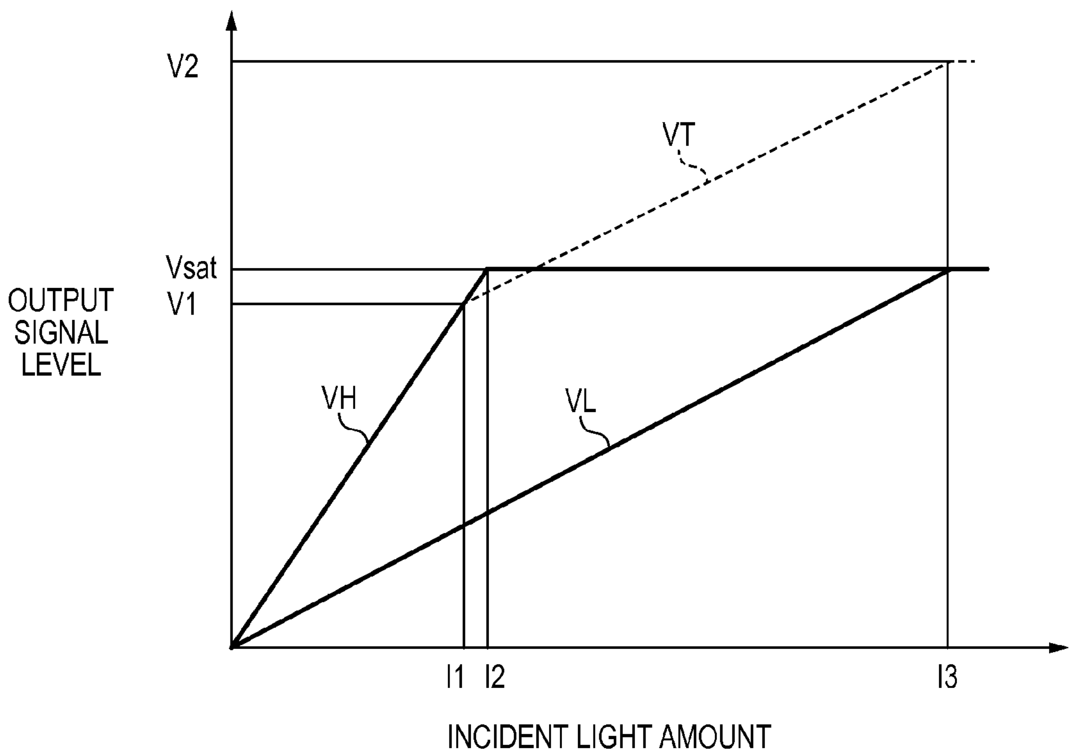
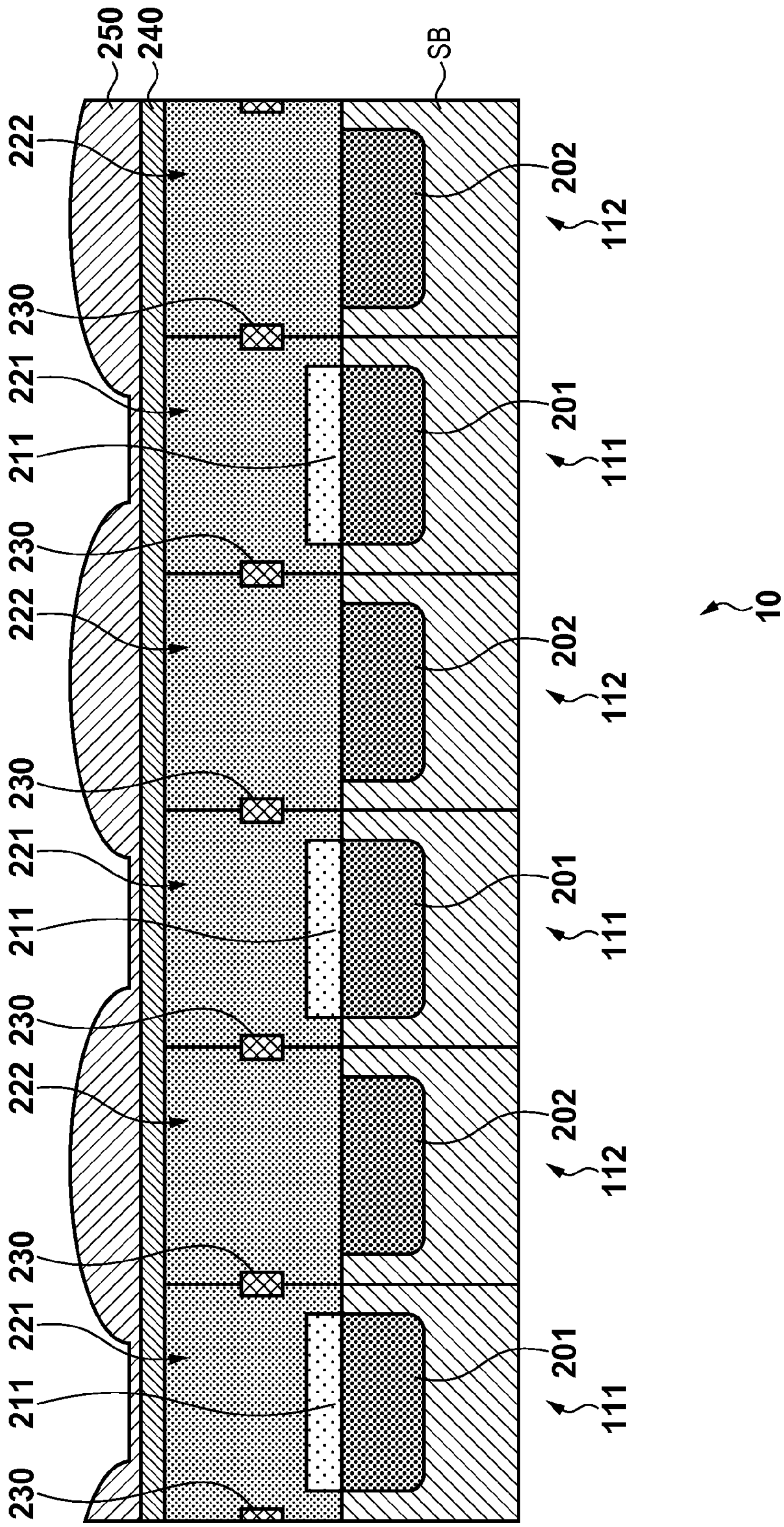
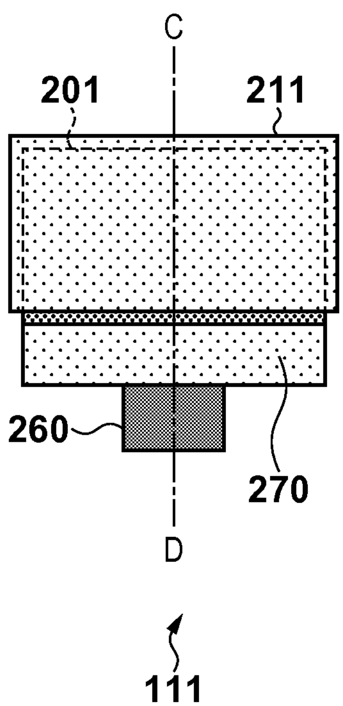

V2
VT
Vsat
V1
OUTPUT SIGNAL LEVEL
VH
VL
I1
I2
I3
INCIDENT LIGHT AMOUNT

FIG. 6



F I G. 7A



F I G. 7B

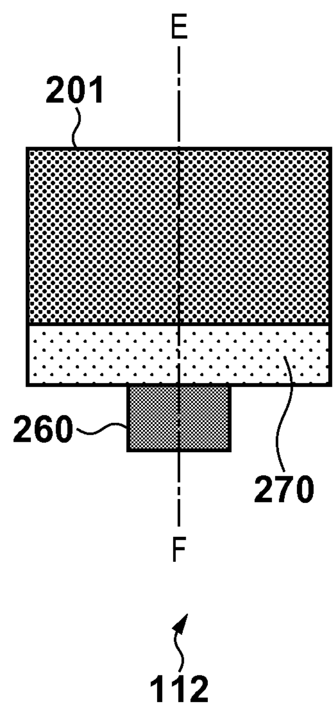


FIG. 8

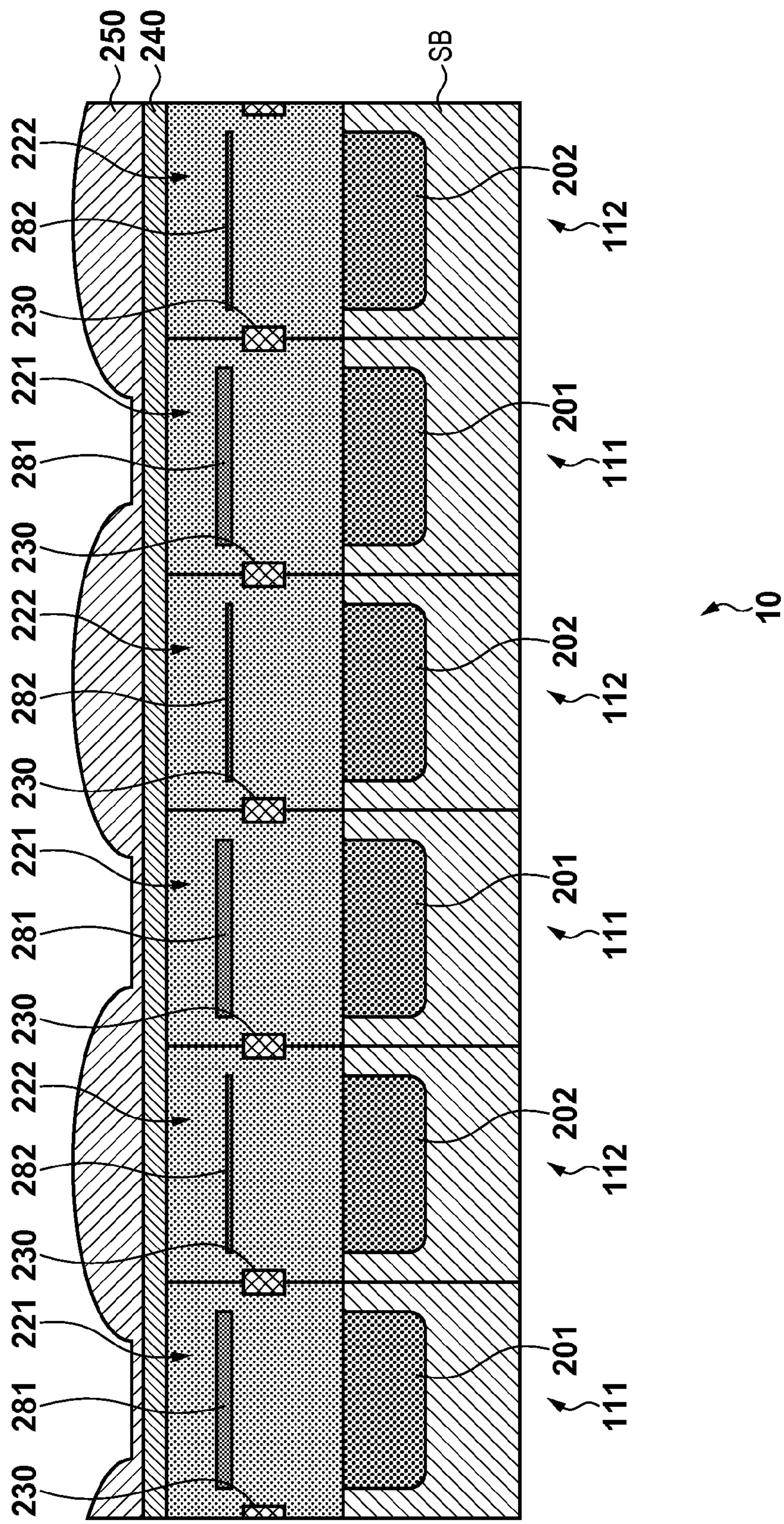


FIG. 9A

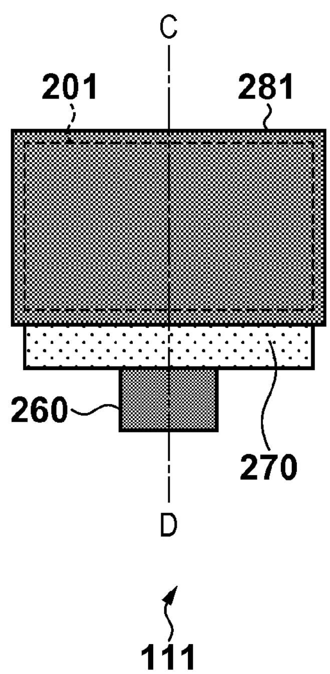
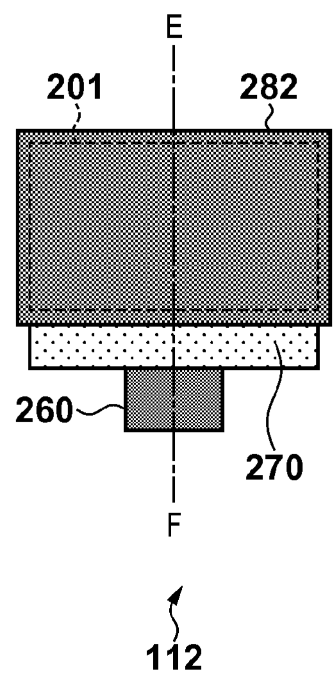
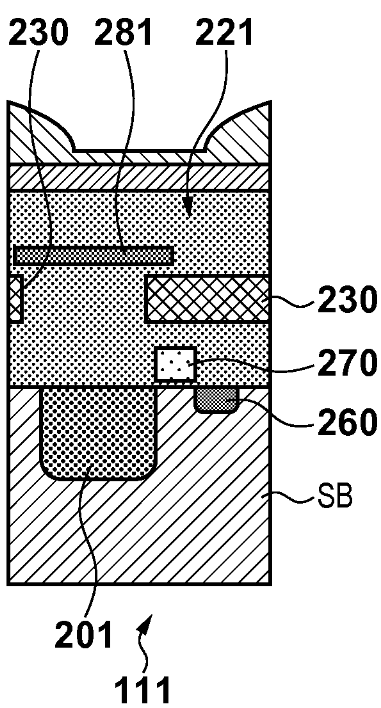


FIG. 9B

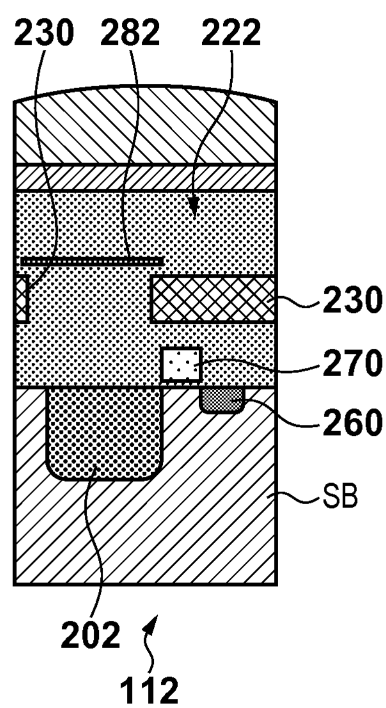


F I G. 10A



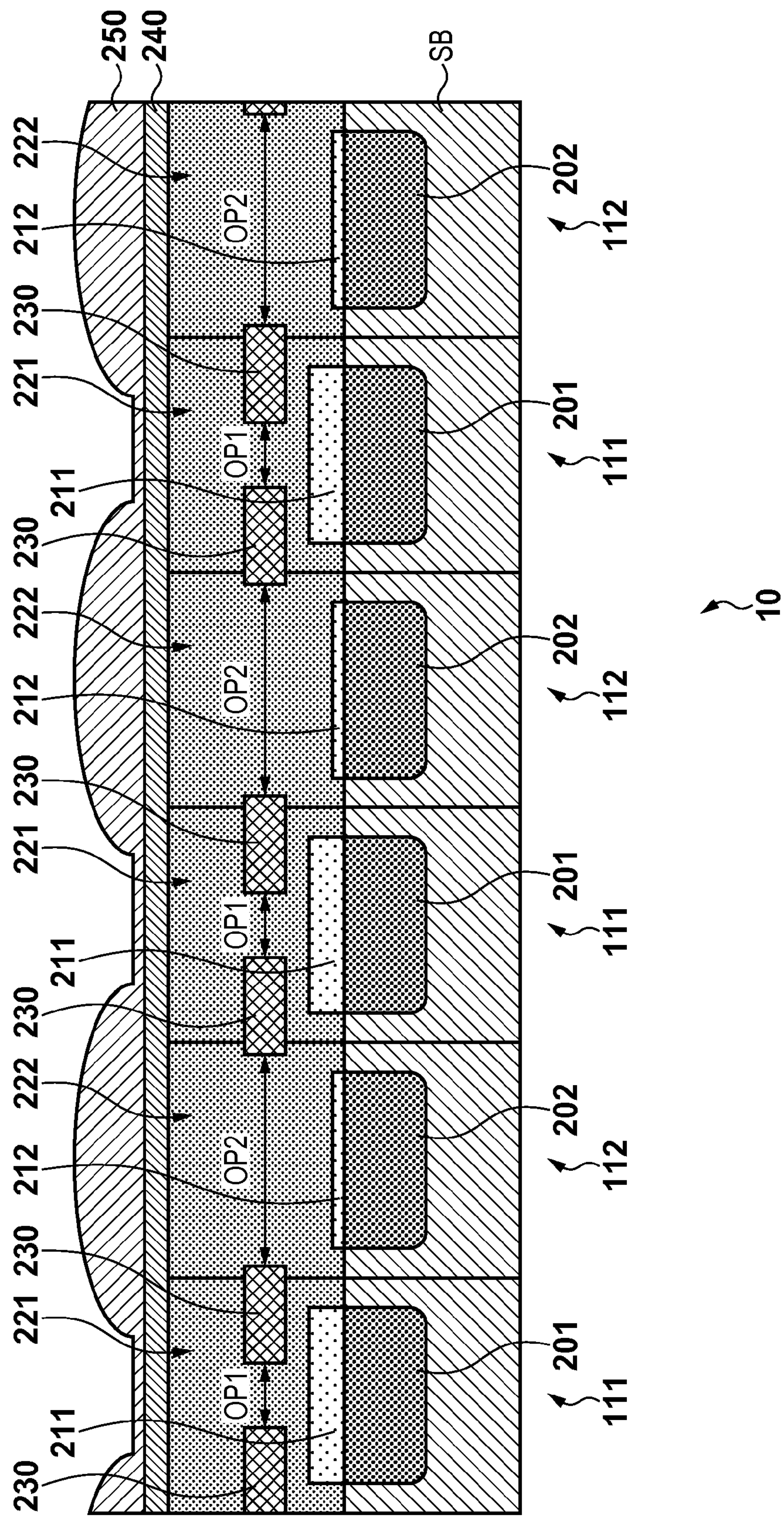
C-D SECTION

F I G. 10B

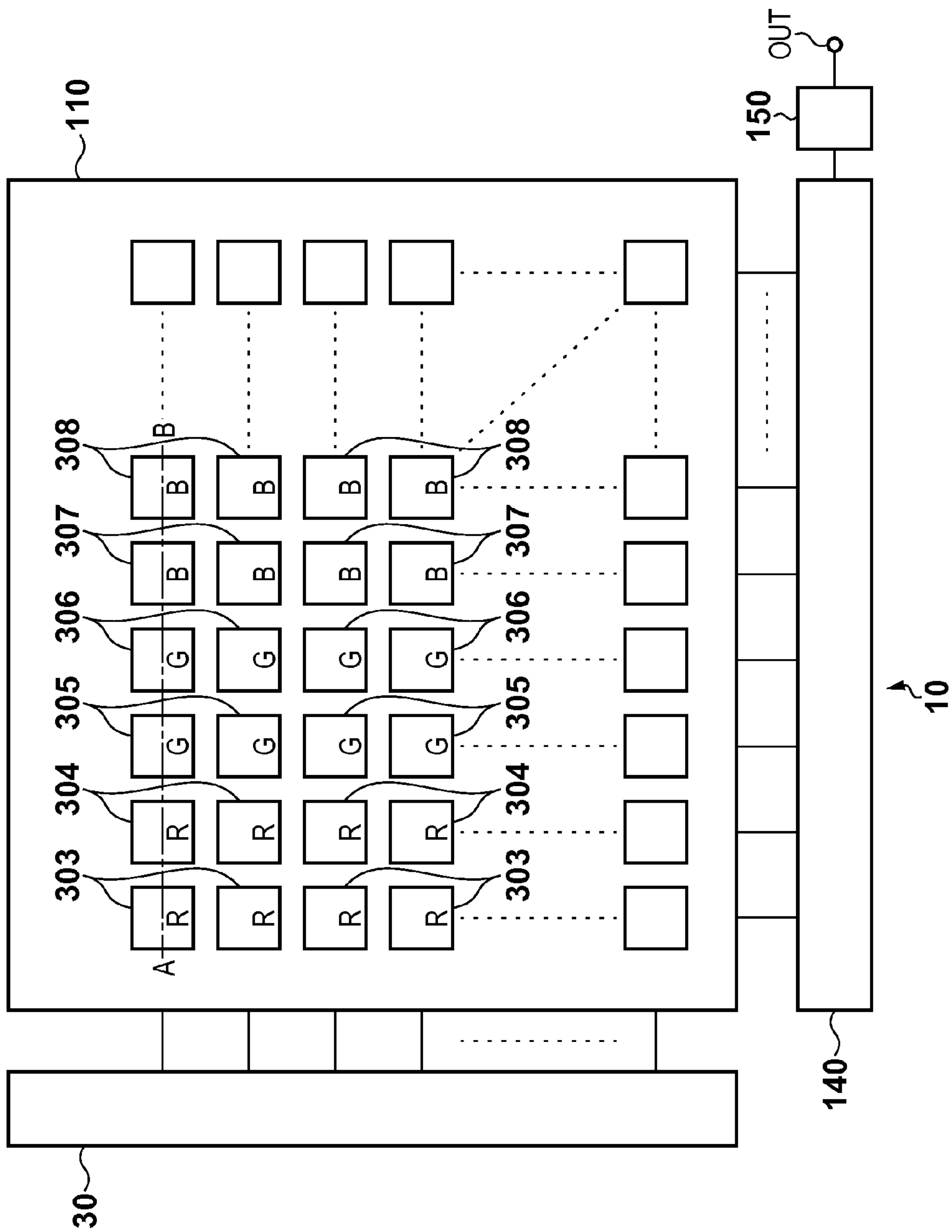


E-F SECTION

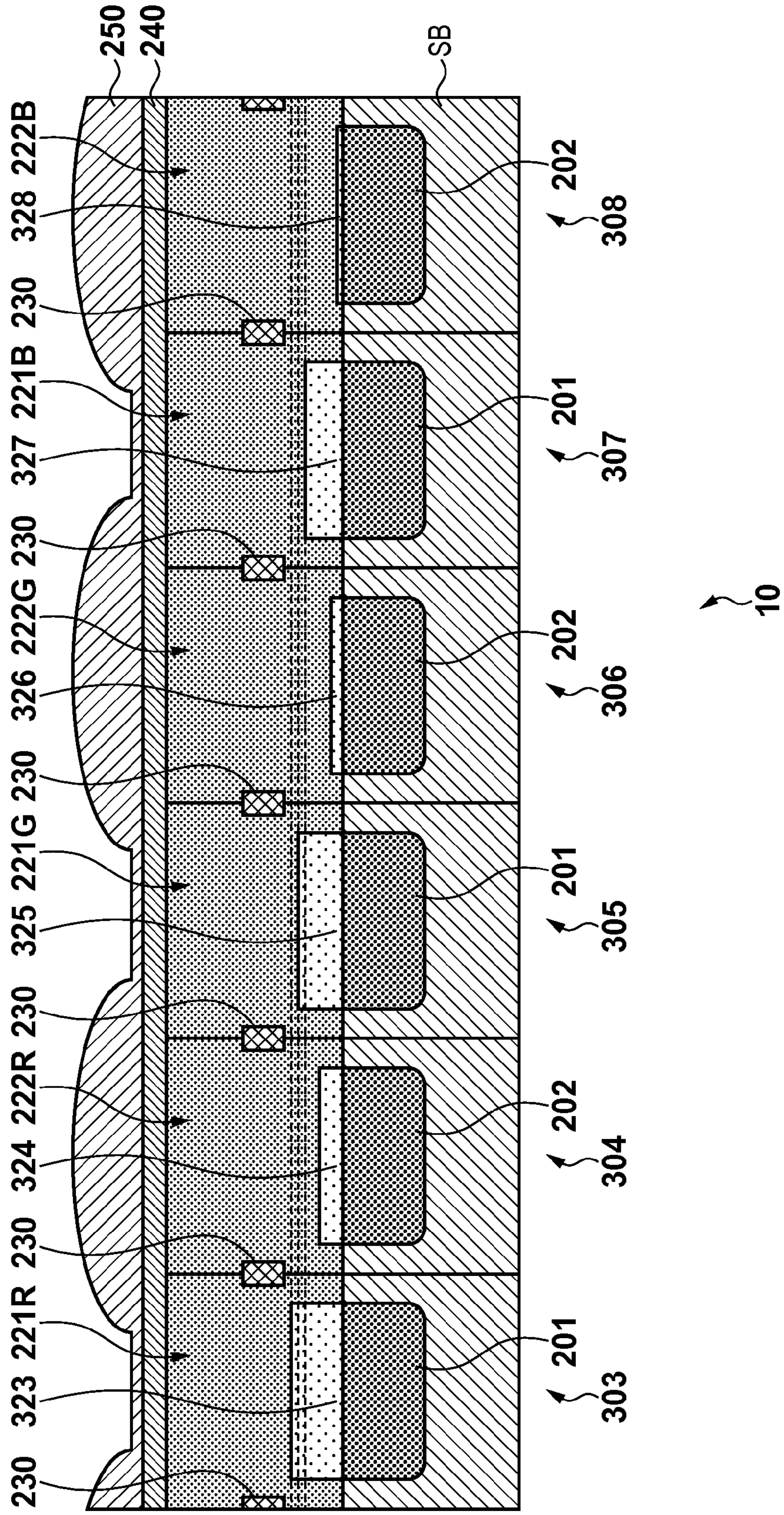
FIG. 11



F I G. 12

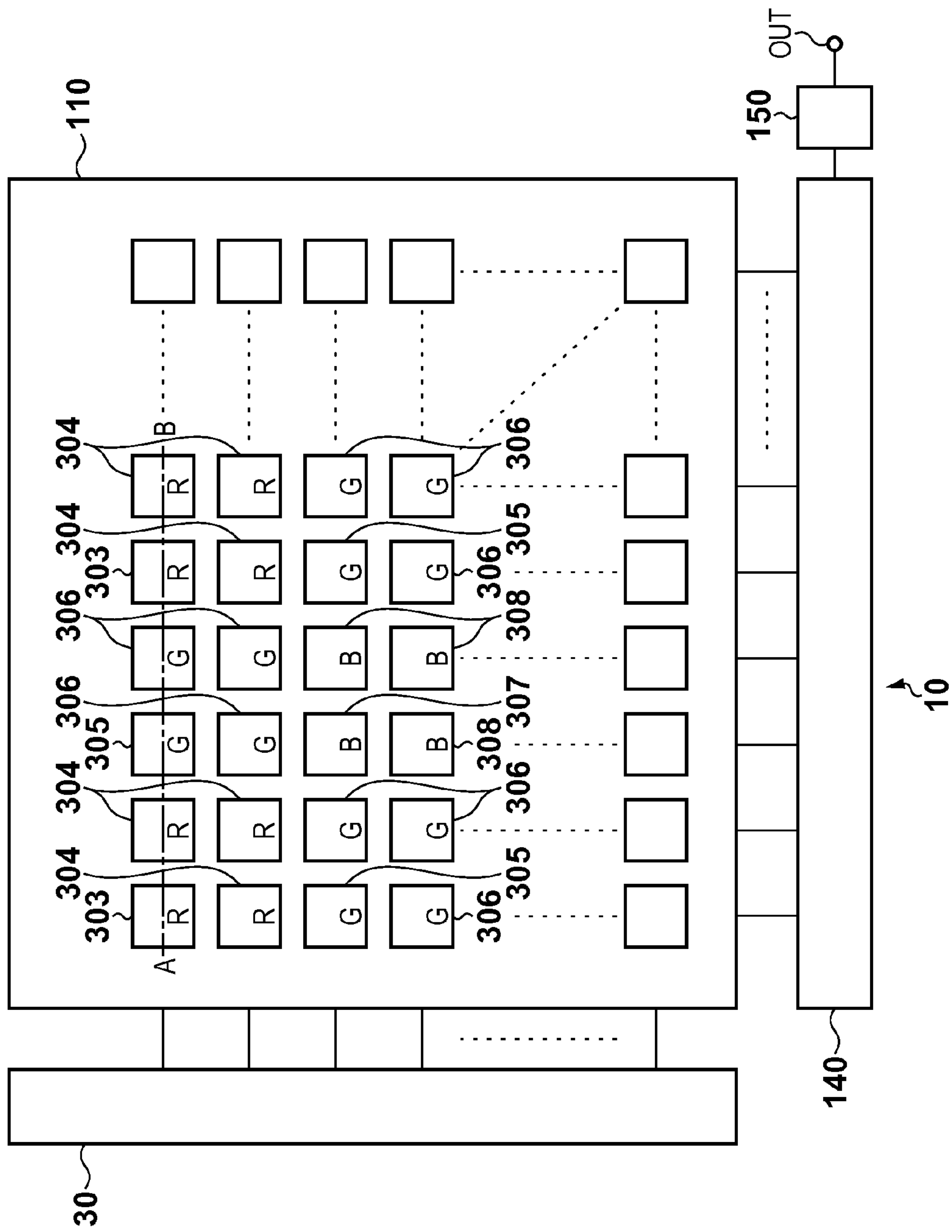


F I G. 13



250
240
SB
222B
328
230
221B
327
230
222G
326
230
221G
325
230
222R
324
230
221R
323
230
202
308
201
307
202
306
201
305
202
304
201
303
10

F I G. 14



SOLID-STATE IMAGE SENSOR AND CAMERA UTILIZING LIGHT ATTENUATING FILMS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a solid-state image sensor and camera.

2. Description of the Related Art

Japanese Patent Laid-Open No. 2004-32059 describes that in order to widen the dynamic range of a solid-state image sensor, a highly sensitivity pixel and low sensitive pixel are formed, and a microlens is formed in only the highly sensitivity pixel of the highly and low sensitivity pixels.

To obtain a wider dynamic range, however, the idea described in Japanese Patent Laid-Open No. 2004-32059 is insufficient. In particular, Japanese Patent Laid-Open No. 2004-32059 has no idea of attenuating light entering the low sensitive pixel in order to widen the dynamic range on a high-illumination side, that is, widen the dynamic range of the low sensitive pixel.

SUMMARY OF THE INVENTION

The present invention provides a technique advantageous in further widening a dynamic range.

One of aspects of the present invention provides a solid-state image sensor comprising a plurality of first pixels each including one of a red color filter, a green color filter, and a blue color filter, and a plurality of second pixels each including one of a red color filter, a green color filter, and a blue color filter, wherein each of the plurality of first pixels includes a first photoelectric converter, and a first light transmissive portion arranged above the first photoelectric converter, and each of the plurality of second pixels includes a second photoelectric converter, and a second light transmissive portion arranged above the second photoelectric converter, in the first pixel and the second pixel including color filters of the same color, light transmittances of the first light transmissive portion and the second light transmissive portion are different, and a light transmittance of the first light transmissive portion of the first pixel including the red color filter is lower than that of the first light transmissive portion of the first pixel including the green color filter, and a light transmittance of the first light transmissive portion of the first pixel including the green color filter is lower than that of the first light transmissive portion of the first pixel including the blue color filter.

Further features of the present invention will become apparent from the following description of exemplary embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic plan view of a solid-state image sensor of a reference example;

FIG. **2** is a sectional view taken along a line A-B in FIG. **1**;

FIG. **3**A is a sectional view taken along a line C-D in FIG. **1**;

FIG. **3**B is a sectional view taken along a line E-F in FIG. **1**;

FIG. **4**A is a plan view of a first pixel in the reference example;

FIG. **4**B is a plan view of a second pixel in the reference example;

FIG. **5** is a view for explaining the widening of a dynamic range;

FIG. **6** is a sectional view taken along the line A-B in FIG. **1** in the reference example;

FIG. **7**A is a plan view of the first pixel in the reference example;

FIG. **7**B is a plan view of the second pixel in the reference example;

FIG. **8** is a sectional view taken along the line A-B in FIG. **1** in the reference example;

FIG. **9**A is a plan view of the first pixel in the reference example;

FIG. **9**B is a plan view of the second pixel in the reference example;

FIG. **10**A is a sectional view taken along the line C-D in FIG. **1** in the reference example;

FIG. **10**B is a sectional view taken along the line E-F in FIG. **1** in the reference example;

FIG. **11** is a sectional view taken along the line A-B in FIG. **1** in the reference example;

FIG. **12** is a schematic plan view of a solid-state image sensor of the first embodiment;

FIG. **13** is a sectional view taken along a line A-B in FIG. **12**; and

FIG. **14** is a schematic plan view of a solid-state image sensor of the second embodiment.

DESCRIPTION OF THE EMBODIMENTS

FIG. **1** is a schematic plan view of a solid-state image sensor **10** of a reference example. The solid-state image sensor **10** includes a pixel array **110** in which a plurality of pixels are arranged to form a plurality of rows and a plurality of columns. In the solid-state image sensor **10**, the plurality of pixels forming the pixel array **110** include a plurality of first pixels **111** and a plurality of second pixels **112**. In the first embodiment, the first pixels **111** are low sensitive pixels, and the second pixels **112** are highly sensitivity pixels. However, the first pixels **111** may also be highly sensitivity pixels, and the second pixels may also be low sensitive pixels. The dynamic range can be widened by generating one signal based on signals of the first pixels **111** and second pixels **112**.

The solid-state image sensor **10** includes a row selecting circuit **130** for selecting a row of the pixel array **110**, a readout circuit **140** for reading out signals output from pixels on a selected row of the pixel array **110**, and an output circuit **150** for processing signals output from the readout circuit **140** and outputting the processed signals. The readout circuit **140** can be designed to output, to the output circuit **150**, signals read out from the first pixel **111** and second pixel **112** adjacent to each other as separate signals. Alternatively, the readout circuit **140** may synthesize signals read out from the first pixel **111** and second pixel **112** adjacent to each other into one signal, and output the synthetic signal to the output circuit **150**. The readout circuit **140** may also include an A/D converter, and a processing circuit for processing a signal converted by the A/D converter.

FIG. **2** is a sectional view taken along a line A-B in FIG. **1**. FIG. **3**A is a sectional view taken along a line C-D in FIG. **1**. FIG. **3**B is a sectional view taken along a line E-F in FIG. **1**.

FIGS. **4**A and **4**B are plan views of the first pixel **111** and second pixel **112**, respectively. The first pixel **111** includes a first photoelectric converter **201**, and a first light transmissive portion **221** arranged above the first photoelectric converter **201**. The second pixel **112** includes a second photoelectric converter **202**, and a second light transmissive portion **222** arranged above the second photoelectric converter **202**. The first and second photoelectric converters **201** and **202** can be formed in a semiconductor substrate SB. The first and second light transmissive portions **221** and **222** have different light transmittances. In the reference example, the first pixel **111** is a low sensitive pixel, and the second pixel **112** is a highly sensitivity pixel, so the light transmittance of the first light transmissive portion **221** is made lower than that of the second light transmissive portion **222**. In other words, the ratio of the amount of light reaching the first photoelectric converter **201** to the amount of light having entered the first light transmissive portion **221** is lower than the ratio of the amount of light reaching the second photoelectric converter **202** to the amount of light having entered the second light transmissive portion **222**.

The first light transmissive portion **221** includes a first light attenuating film **211**, the second light transmissive portion **222** includes a second light attenuating film **212**, and the lower surfaces of the first and second light attenuating films **211** and **212** can exist at the same height with respect to the surface of the semiconductor substrate SB. The first and second light attenuating films **211** and **212** function as members for attenuating light.

The first light transmissive portion **221** can include a first insulating film **215**. The first insulating film **215** is in contact with the first light attenuating film **211** and made of a material different from that of the first light attenuating film **211**. The second light transmissive portion **222** can include a second insulating film **216**. The second insulating film **216** is in contact with the second light attenuating film **212** and made of a material different from that of the second light attenuating film **212**. When the first and second light attenuating films **211** and **212** are made of the same material, the thickness of the first light attenuating film **211** is made larger than that of the second light attenuating film **212** so as to make the light transmittance of the first light transmissive portion **221** lower than that of the second light transmissive portion **222**. The first and second light attenuating films **211** and **212** can be made of, for example, polysilicon. The first and second light attenuating films **211** and **212** respectively cover at least portions of the first and second photoelectric converters **201** and **202**.

The first pixel **111** can have a first opening OP**1** formed in a light-shielding layer **230**, and the second pixel **112** can have a second opening OP**2** formed in the light-shielding layer **230**. In the light-shielding layer **230**, a portion that defines the first opening OP**1** and a portion that defines the second opening OP**2** can be either continuous or separated from each other. The light-shielding layer **230** may also function as a wiring layer.

The solid-state image sensor **10** can include a color filter layer **240** above the first and second light transmissive portions **221** and **222**. The solid-state image sensor **10** can also include an optical member array (for example, a microlens array) **250** above the first and second light transmissive portions **221** and **222**, for example, above the color filter layer **240**. The optical member array **250** can include first optical members **251** formed for the first pixels **111**, and second optical members **252** formed for the second pixels **112**. In the reference example as described above, to form the first pixel **111** as a low sensitive pixel and the second pixel **112** as a highly sensitivity pixel, the light transmittance of the first light transmissive portion **221** is made lower than that of the second light transmissive portion **222**. Under the condition, the amount of light entering the first light transmissive portion **221** through the first optical member **251** is preferably smaller than that of light entering the second light transmissive portion **222** through the second optical member **252**. This makes it possible to increase the sensitivity difference between the first and second pixels **111** and **112**, and widen the dynamic range. The first optical member **251** can be, for example, a parallel plate member or a microlens (for example, a concave lens or convex lens). The second optical member **252** can be a microlens.

When the solid-state image sensor **10** is designed as a MOS sensor, each of the first and second pixels **111** and **112** can have a transfer gate **270** for transferring an electric charge stored in the first or second photoelectric converter **201** or **202** to a floating diffusion **260**.

The widening of the dynamic range will be explained with reference to FIG. **5**. The level (voltage) of a signal VH of the first pixel **111** formed as a highly sensitivity pixel becomes a saturated level Vsat corresponding to a saturated charge quantity with a light amount **12**. Since the saturated level of a pixel varies, the signal VH of the first pixel **111** formed as a highly sensitivity pixel is used to a level V**1** corresponding to a highly linear light amount I**1**, and a signal VL of the second pixel **112** formed as a low sensitive pixel is used after the light amount I**1** is exceeded. A synthetic signal VT can be obtained by adding the level of the signal VL to the level V**1** of the signal VH corresponding to the light amount I**1**. Consequently, a detectable light amount becomes **0** to I**3**, and the dynamic range widens.

In the example shown in FIGS. **2**, **3**A, **3**B, **4**A, and **4**B, the light transmittances of the first and second light transmissive portions **221** and **222** are made different from each other by making the light transmittances of the first and second light attenuating films **211** and **212** of the first and second light transmissive portions **221** and **222** different from each other. Instead, as shown in FIGS. **6**, **7**A, and **7**B, the light transmittances of the first and second light transmissive portions **221** and **222** can also be made different from each other by removing the second light attenuating film **212** of the second light transmissive portion **222**.

FIGS. **8**, **9**A, **9**B, **10**A, and **10**B illustrate first and second light attenuating films **281** and **282** that can be formed instead of or together with the first and second light attenuating films **211** and **212**. The first and second light attenuating films **281** and **282** can be arranged in positions higher than the transfer gate **270** with respect to the surface of the semiconductor substrate SB. Each of the first and second light attenuating films **281** and **282** can be formed by a metal film or metal compound film having a thickness so determined as to transmit light.

As shown in FIG. **11**, in the arrangement in which the light transmittance of the first light transmissive portion **221** is lower than that of the second light transmissive portion **222**, the area of the first opening OP**1** of the first pixel **111** may be made smaller than that of the opening OP**2** of the second pixel **112**. This makes it possible to increase the sensitivity difference between the first and second pixels **111** and **112**, and widen the dynamic range.

A solid-state image sensor **10** of the first embodiment of the present invention will be explained with reference to FIGS. **12** and **13**. Note that items not mentioned in the first embodiment can follow those of the reference example. FIG. **12** is a schematic plan view of the solid-state image sensor **10** of the first embodiment of the present invention. FIG. **13** is a sectional view taken along a line A-B in FIG. **12**. The solid-state image sensor **10** of the first embodiment includes red (R) pixels **303** and **304**, green (G) pixels **305** and **306**, and blue (B) pixels **307** and **308**. The color of a pixel is determined by the color of a color filter arranged in a color filter layer **240**. That is, the pixels **303** and **304** are pixels including color filters of red (for example, a first color), the pixels **305** and **306** are pixels including color filters of green (for example, a second color), and the pixels **307** and **308** are pixels including color filters of blue (for example, a third color).

Of the red pixels **303** and **304**, the pixel **303** corresponds to the first pixel **101** in the reference example, and the pixel **304** corresponds to the second pixel **102** in the reference example. Similarly, of the green pixels **305** and **306**, the pixel **305** corresponds to the first pixel **101** in the reference example, and the pixel **306** corresponds to the second pixel **102** in the reference example. Of the blue pixels **307** and **308**, the pixel **307** corresponds to the first pixel **101** in the reference example, and the pixel **308** corresponds to the second pixel **102** in the reference example.

In the first embodiment, the light transmittance of a first light transmissive portion **221** of the first pixel having a color filter of a given color is different from that of the first light transmissive portion **221** of the first pixel having a color filter of a different color.

A more practical example will be explained below. The red pixels **303** and **304** have the peak of the spectral sensitivity characteristic at a wavelength near, for example, 600 nm. The pixel **303** is the first pixel as a low sensitive pixel, and the pixel **304** is the second pixel as a highly sensitivity pixel. The green pixels **305** and **306** have the peak of the spectral sensitivity characteristic at a wavelength near, for example, 550 nm. The pixel **305** is the first pixel as a low sensitive pixel, and the pixel **306** is the second pixel as a highly sensitivity pixel. The blue pixels **307** and **308** have the peak of the spectral sensitivity characteristic at a wavelength near, for example, 450 nm. The pixel **307** is the first pixel as a low sensitive pixel, and the pixel **308** is the second pixel as a highly sensitivity pixel.

The red first pixel **303** includes a first photoelectric converter **201**, and a first light transmissive portion **221**R arranged above the first photoelectric converter **201**. The red second pixel **304** includes a second photoelectric converter **202**, and a second light transmissive portion **222**R arranged above the second photoelectric converter **202**. The green first pixel **305** includes a first photoelectric converter **201**, and a first light transmissive portion **221**G arranged above the first photoelectric converter **201**. The green second pixel **306** includes a second photoelectric converter **202**, and a second light transmissive portion **222**G arranged above the second photoelectric converter **202**. The blue first pixel **307** includes a first photoelectric converter **201**, and a first light transmissive portion **221**B arranged above the first photoelectric converter **201**. The blue second pixel **308** includes a second photoelectric converter **202**, and a second light transmissive portion **222**B arranged above the second photoelectric converter **202**. First light attenuating films **323**, **325**, and **327** of the first light transmissive portions **221**R, **221**G, and **221**B and second light attenuating films **324**, **326**, and **328** of the second light transmissive portions **222**R, **222**B, and **222**G can be made of, for example, polysilicon.

A light transmittance R**1** of the first light transmissive portion **221**R is lower than a light transmittance R**2** of the second light transmissive portion **222**R. A light transmittance G**1** of the first light transmissive portion **221**G is lower than a light transmittance G**2** of the second light transmissive portion **222**G. A light transmittance B**1** of the first light transmissive portion **221**B is lower than a light transmittance B**2** of the second light transmissive portion **222**B. Also, R**1**<G**1**<B**1** and R**2**<G**2**<B**2** hold.

A film thickness TR**1** of the first light transmissive portion **221**R is larger than a film thickness TR**2** of the second light transmissive portion **222**R. A film thickness TG**1** of the first light transmissive portion **221**G is larger than a film thickness TG**2** of the second light transmissive portion **222**G. A film thickness TB**1** of the first light transmissive portion **221**B is larger than a film thickness TB**2** of the second light transmissive portion **222**B. Also, TR**1**>TG**1**>TB**1** and TR**2**>TG**2**>TB**2** hold.

Polysilicon has a spectral sensitivity characteristic by which the light transmittance increases toward a long-wavelength side in the wavelength region of visible light. Accordingly, when the first light attenuating films **323**, **325**, and **327** and second light attenuating films **324**, **326**, and **328** are made of polysilicon, the color balance worsens if their film thicknesses are determined without taking account of the spectral sensitivity characteristic of polysilicon. In the second embodiment, therefore, first light attenuating films **323**, **325**, and **327** and second light attenuating films **324**, **326**, and **328** are formed such that R**1**<G**1**<B**1** and R**2**<G**2**<B**2** (TR**1**>TG**1**>TB**1** and TR**2**>TG**2**>TB**2**) hold.

A solid-state image sensor **10** of the second embodiment of the present invention will be explained with reference to FIG. **14**. Note that items not mentioned in the second embodiment can follow those of the first embodiment. In the second embodiment, as shown in FIG. **14**, a red (R) pixel group (**303** and **304**), a green (G) pixel group (**305** and **306**), and a blue (B) pixel group (**307** and **308**) form a Bayer array. The red pixel group includes one first pixel (low sensitive pixel) **303** and three second pixels (highly sensitivity pixels) **304**. The green pixel group includes one first pixel (low sensitive pixel) **305** and three second pixels (highly sensitivity pixels) **306**. The blue pixel group includes one first pixel (low sensitive pixel) **307** and three second pixels (highly sensitivity pixels) **308**. In this arrangement, the barycenter of a low sensitive pixel can be positioned close to that of (three) highly sensitivity pixels forming the same pixel group as that of the low sensitive pixel. The second embodiment is also applicable to another color filter array.

The features of the present invention do not limit the structure of a pixel and the method of a solid-state image sensor. For example, the present invention is applicable to MOS solid-state image sensors having various pixel arrangements, and is also applicable to CCD solid-state image sensors having various pixel arrangements.

As an application example of the solid-state image sensor according to each of the above embodiments, a camera incorporating the solid-state image sensor will be explained below. The concept of the camera includes not only an apparatus whose main purpose is imaging, but also an apparatus (for example, a personal computer or portable terminal) having an imaging function as an auxiliary function. The camera can include the solid-state image sensor according to the present invention exemplified in the above-mentioned embodiments, and a processing unit that processes an output signal from the solid-state image sensor. This processing unit can include an A/D converter, and a processor that processes digital data output from the A/D converter.

While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

This application claims the benefit of Japanese Patent Application No. 2013-048489, filed Mar. 11, 2013, which is hereby incorporated by reference herein in its entirety.

What is claimed is:

1. A solid-state image sensor comprising a plurality of first pixels each including one of a red color filter, a green color filter, and a blue color filter, and a plurality of second pixels each including one of a red color filter, a green color filter, and a blue color filter, wherein

each of the plurality of first pixels includes a first photoelectric converter, and a first light transmissive portion having a first light attenuating film and arranged above the first photoelectric converter, and each of the plurality of second pixels includes a second photoelectric converter, and a second light transmissive portion having a second light attenuating film and arranged above the second photoelectric converter,

the first and the second light attenuating films for the same color are configured such that light transmittances of the first and second light transmissive portions of the same color are different, and

the first attenuating film is further configured such that a light transmittance of the first light transmissive portion of the first pixel including the red color filter is lower than that of the first light transmissive portion of the first pixel including the green color filter, and a light transmittance of the first light transmissive portion of the first pixel including the green color filter is lower than that of the first light transmissive portion of the first pixel including the blue color filter.

2. The sensor according to claim **1**, wherein

the first pixel has a first opening formed in a light-shielding layer, and the second pixel has a second opening formed in the light-shielding layer, and

a light transmittance of the first light transmissive portion is lower than that of the second light transmissive portion, and an area of the first opening is smaller than that of the second opening.

3. The sensor according to claim **1**, wherein

the first pixel includes a first optical member above the first light transmissive portion, and the second pixel includes a second optical member above the second light transmissive portion, and

a light transmittance of the first light transmissive portion is lower than that of the second light transmissive portion, and an amount of light entering the first light transmissive portion through the first optical member is smaller than that of light entering the second light transmissive portion through the second optical member.

4. The sensor according to claim **1**, wherein the first light transmissive portions of the plurality of first pixels and the second light transmissive portions of the plurality of second pixels are arranged below a layer where the red, green and blue color filters of the plurality of first pixels and the red, green and blue color filters of the plurality of second pixels are arranged.

5. The sensor according to claim **1**, wherein the first photoelectric converters of the plurality of first pixels and the second photoelectric converters of the plurality of second pixels have the same size.

6. A solid-state image sensor, comprising a plurality of first pixels each including one of a red color filter, a green color filter, and a blue color filter, and a plurality of second pixels each including one of a red color filter, a green color filter, and a blue color filter, wherein

each of the plurality of first pixels includes a first photoelectric converter, and a first light transmissive portion arranged above the first photoelectric converter, and each of the plurality of second pixels includes a second photoelectric converter, and a second light transmissive portion arranged above the second photoelectric converter,

in the first pixel and the second pixel including color filters of the same color, light transmittances of the first light transmissive portion and the second light transmissive portion are different from each other,

a light transmittance of the first light transmissive portion of the first pixel including the red color filter is lower than that of the first light transmissive portion of the first pixel including the green color filter, and a light transmittance of the first light transmissive portion of the first pixel including the green color filter is lower than that of the first light transmissive portion of the first pixel including the blue color filter, and

the first photoelectric converter and the second photoelectric converter are formed in a semiconductor substrate, the first light transmissive portion includes a first light attenuating film, the second light transmissive portion includes a second light attenuating film, and the first light attenuating film and the second light attenuating film are made of the same material and have thicknesses different from each other.

7. The sensor according to claim **6**, wherein lower surfaces of the first light attenuating film and the second light attenuating film exist at the same height with respect to a surface of the semiconductor substrate.

8. The sensor according to claim **6**, wherein the first light transmissive portion includes a first insulating film contacting the first light attenuating film and made of a material different from that of the first light attenuating film, and the second light transmissive portion includes a second insulating film contacting the second light attenuating film and made of a material different from that of the second light attenuating film.

9. The sensor according to claim **6**, wherein the first light attenuating film and the second light attenuating film are made of polysilicon.

10. The sensor according to claim **6**, wherein each of the first light attenuating film and the second light attenuating film is formed by one of a metal film and a metal compound film whose thickness is determined such that light is transmitted.

11. A camera comprising:

a solid-state image sensor comprising a plurality of first pixels, each including one of a red color filter, a green color filter, and a blue color filter, and a plurality of second pixels, each including one of a red color filter, a green color filter, and a blue color filter; and

a processing unit configured to process an output signal from the solid-state image sensor, wherein

each of the plurality of first pixels further includes a first photoelectric converter, and a first light transmissive portion having a first light attenuating film and arranged above the first photoelectric converter and each of the sluralit of second sixels further includes a second photoelectric converter, and a second light transmissive portion having a second light attenuating film and arranged above the second photoelectric converter,

the first and second light attenuating films for the same color are configured such that light transmittances of the first and second light transmissive portions of the same color are different from each other, and

the first attenuating film is further configured such that a light transmittance of the first light transmissive portion of the first pixel including the red color filter is lower than that of the first light transmissive portion of the first pixel including the green color filter, and a light transmittance of the first light transmissive portion of the first pixel including the green color filter is lower than that of the first light transmissive portion of the first pixel including the blue color filter.

12. A solid-state image sensor comprising a plurality of first pixels each including one of a red color filter, a green color filter, and a blue color filter, and a plurality of second pixels each including one of a red color filter, a green color filter, and a blue color filter, wherein

each of the plurality of first pixels includes a first photoelectric converter, and a first light transmissive portion arranged above the first photoelectric converter, and each of the plurality of second pixels includes a second photoelectric converter, and a second light transmissive portion arranged above the second photoelectric converter,

in the first pixel and the second pixel including color filters of the same color, light transmittances of the first light transmissive portion and the second light transmissive portion of the same color are different from each other,

a light transmittance of the first light transmissive portion of the first pixel including the red color filter is lower than that of the first light transmissive portion of the first pixel including the green color filter, and a light transmittance of the first light transmissive portion of the first pixel including the green color filter is lower than that of the first light transmissive portion of the first pixel including the blue color filter, and

the first light transmissive portion includes a first light attenuating film, the second light transmissive portion includes a second light attenuating film, and the first light attenuating film and the second light attenuating film are made of the same material and have thicknesses different from each other.

* * * * *